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MANEUVER ACCELERATIONS EXPERIENCED DURING ROUTINE OPERATIONS OF A COMMERCIAL TURBOJET TRANSPORT AIRPLANE

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MANEUVER ACCELERATIONS EXPERIENCED DURING ROUTINE OPERATIONS OF A COMMERCIAL TURBOJET TRANSPORT AIRPLANE

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SUMMARY

The incremental maneuver normal accelerations collected during both passenger-carrying operational flights and check and training flights of a four-engine turbojet commercial transport airplane have been evaluated. The frequency of occurrence of maneuver accelerations per mile of flight for climb was approximately the same as that for descent. The frequency of occurrence for each of these two flight conditions was about ten times that during cruise. This tendency is typical of transport operations, particularly for the turbojet transports.

INTRODUCTION

Maneuvers constitute one of the major load sources which has to be considered in estimating the loads likely to be experienced by the supersonic transport. Two approaches to the estimation of maneuver loads on the supersonic transport are currently being considered. One method consists of judiciously applying maneuver data obtained on subsonic jet transports to the supersonic transport by properly adjusting for differences in flight profiles and operational regimes. The other method envisages simulating the supersonic transport on a flight simulator and measuring the maneuver loads as the airplane is flown according to the anticipated flight profiles. The validity of the use of the simulator can be examined by first simulating a subsonic jet transport and comparing the maneuver data from the simulator with data actually measured during routine airline operations. In order to utilize either of the two approaches to the maneuver loads estimation for the supersonic transport, information on the maneuver loads experienced by subsonic jet transports is required.

Overall distributions of maneuver loads obtained from VGH recorders installed on several types of subsonic jet transports are given in reference 1. In order to provide maneuver loads data in more detail than is given in reference 1, a sample of VGH records covering about 1,200 hours of operations of a four-engine turbojet transport has been evaluated to obtain the detailed distributions of maneuver loads experienced during routine operational flights and during check and training flights. In addition to overall distributions, distributions of positive and

negative accelerations, and distributions by flight condition are presented herein.

INSTRUMENTATION AND SCOPE OF DATA

The data were collected with an NASA VGH recorder which provides continuous time-history records of the indicated airspeed, pressure altitude, and normal acceleration. A detailed description of the VGH recorder is given in reference 2. The remote VGH acceleration sensor was located in the main-landing-gear wheel well approximately 3 inches from the airplane center line. Recorder pressure lines were connected to the copilot's airspeed system.

The present data were obtained from transcontinental United States and trans-Pacific routes during operations between March 1960 and June 1962. The data sample consists of 1,205 hours of operational VGH records covering 389 flights of a single airplane and 17 hours of check-flight records. Operational flights were scheduled routine passenger-carrying transport flights and check flights were nonpassenger-carrying flights during which airplane and pilot checks were performed.

The average length of flight for these operations was about 185 minutes, but the distribution of flight duration shown in figure 1 indicates that the flights

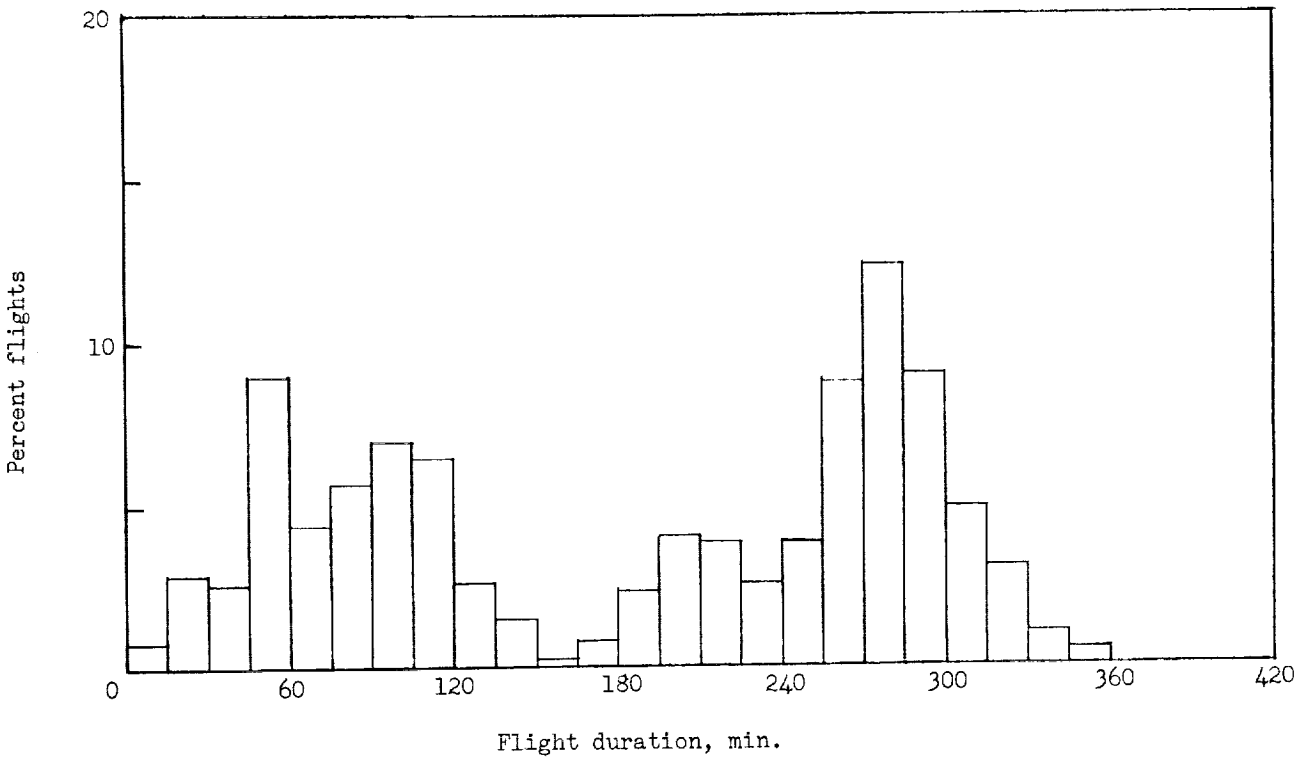
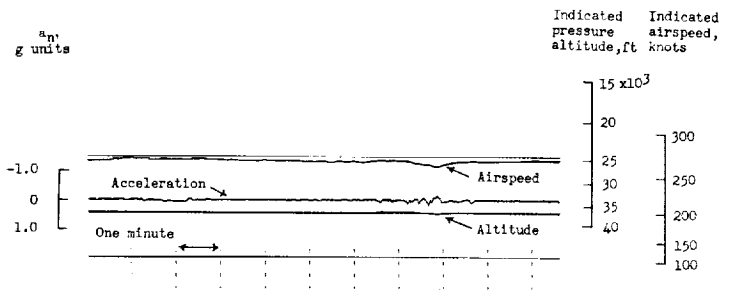
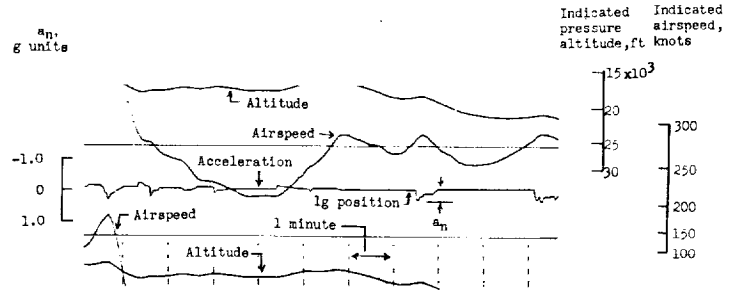


Figure 1.- Percent of total flights having given flight duration.



(a) Operational-maneuver accelerations.



(b) Check-flight-maneuver accelerations.

Figure 2.- Sample VGH records.

were essentially of two lengths, approximately $1\frac{1}{2}$ hours and $4\frac{1}{2}$ hours. Operational flights were fairly well distributed over the recording period and covered all seasons. Check flights occurred randomly during the recording period and accounted for 1.4 percent of the total recorded time.

Evaluation of Data

Normal accelerations experienced during operational and check-flight maneuvers were evaluated by reading each maneuver acceleration greater than a threshold value of ±0.1g relative to the steady flight 1 g value. The procedures used to evaluate maneuver accelerations have been described in detail in previous papers. (See, for example, ref. 3.) Maneuver accelerations are distinguished from gust accelerations generally by a longer period, different acceleration-time variation, and by the lack of high-frequency response in the airspeed trace which accompanies gust accelerations. Only the maximum value is read for each crossing of the 1 g trace position. Operational flights are distinguished from check flights by more uniform variation of the three VGH traces over the duration of the flight. Samples of records from an operational flight and a check flight are shown in figure 2. The method of reading incremental accelerations is indicated on the check-flight sample shown in figure 2.

RELIABILITY OF DATA

The precision of the VGH recorder is discussed in references 1 and 2, and the maximum overall errors are estimated to be:

Acceleration, g units	±0.05
Indicated airspeed, knots:	
At 100 knots	±6
At 300 knots	±2

The count of accelerations exceeding certain values of maneuver accelerations for the total sample is estimated to be within ±20 percent in frequency of occurrence.

TABLE I.- FREQUENCY DISTRIBUTIONS OF POSITIVE AND NEGATIVE MANEUVER ACCELERATIONS DURING OPERATIONAL AND CHECK FLIGHTS

Acceleration, a_n, g units	Frequency for -	
	Operational maneuvers	Check-flight maneuvers
0.6 to 0.7		3
0.5 to 0.6	2	8
0.4 to 0.5	16	10
0.3 to 0.4	124	24
0.2 to 0.3	832	86
0.1 to 0.2	5,446	277
-0.1 to -0.2	4,573	215
-0.2 to -0.3	324	48
-0.3 to -0.4	31	7
-0.4 to -0.5	6	3
Total	11,354	681
Flight hours	1,204.85	1,221.85
Time in check flights, hr	---	17.00
True airspeed (estimated), mph	517	517
Statute flight miles	6.2×10^5	6.3×10^5

TABLE II.- FREQUENCY DISTRIBUTIONS OF POSITIVE AND NEGATIVE MANEUVER ACCELERATIONS BY FLIGHT CONDITION FOR OPERATIONAL FLIGHTS

Acceleration, a_n, g units	Frequency for -		
	Climb	Cruise	Descent
0.5 to 0.6		2	
0.4 to 0.5	5	4	7
0.3 to 0.4	55	13	56
0.2 to 0.3	311	96	425
0.1 to 0.2	1,477	1,336	2,633
-0.1 to -0.2	1,288	1,357	1,928
-0.2 to -0.3	148	73	103
-0.3 to -0.4	21	3	7
-0.4 to -0.5	2	2	2
Total	3,307	2,886	5,161
Flight hours	113.15	936.50	155.20
True airspeed (estimated), mph	422	553	370
Statute flight miles	4.8×10^4	51.8×10^4	5.7×10^4

For smaller data samples, such as distributions by flight condition, the reliability of the count of accelerations is estimated to be within ±30 percent.

RESULTS AND DISCUSSION

The basic data are presented as frequency distributions in tables I and II. Table I gives distributions of positive and negative maneuver accelerations from operational flights and from check flights. Table II contains distributions of positive and negative maneuver accelerations from operational flights only, by flight condition. For each distribution, the number of flight hours, approximate average true airspeed in miles per hour, and the resulting statute flight miles represented are listed. For check flights, the flight miles represent the total of operational and check-flight miles of the sample. Inasmuch as the airspeeds have not been evaluated for the present data sample, the true airspeeds given were obtained from a different operator of the same type of aircraft.

As a check on the validity of the airspeeds used in evaluating the data, the average true airspeed in cruise for 108 randomly selected points from the present data was determined. The excellent agreement between the two average airspeeds indicates that the use of the airspeed obtained from the other operation is valid.

Figure 3 presents the distributions of positive and negative accelerations for operational and check flights in the form of cumulative frequency of occurrence per mile of flight. These data indicate a somewhat higher frequency for

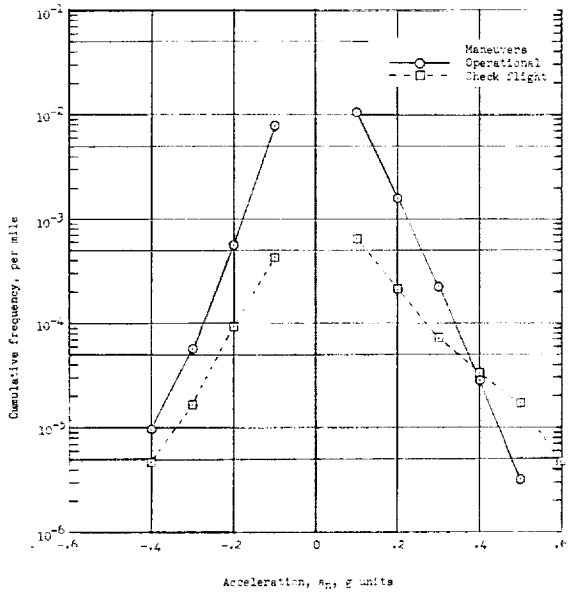


Figure 3.- Cumulative frequency of occurrence of positive and negative maneuver accelerations per mile of flight for operational and check flights.

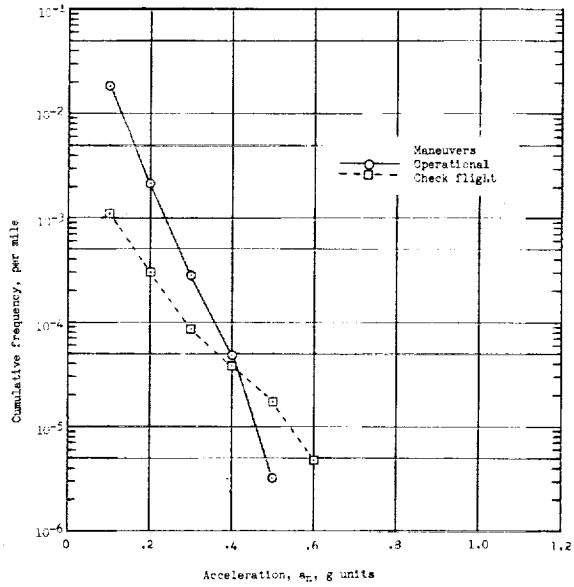


Figure 4.- Cumulative frequency of occurrence of combined positive and negative maneuver accelerations per mile of flight for operational and check flights.

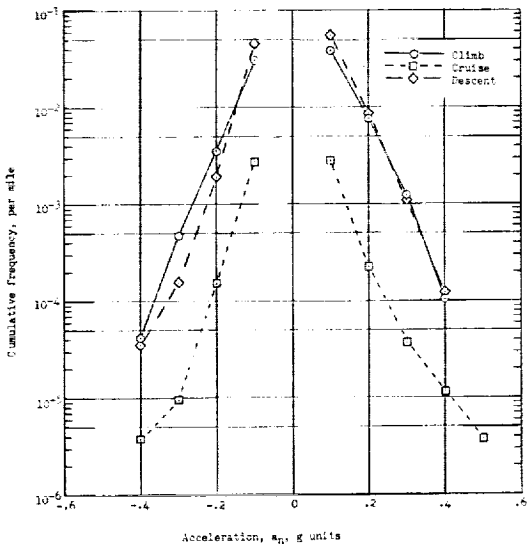


Figure 5.- Cumulative frequency of occurrence of positive and negative maneuver accelerations per mile of flight by flight condition for operational flights.

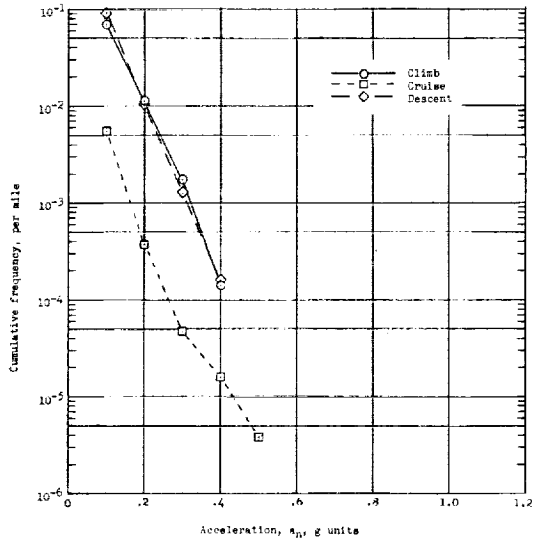


Figure 6.- Cumulative frequency of occurrence of combined positive and negative maneuver accelerations per mile of flight by flight condition for operational flights.

positive maneuver normal accelerations than for the corresponding negative values, particularly for check flights.

The cumulative frequencies of combined positive and negative maneuver accelerations are shown in figure 4. The flatter slope and somewhat higher maximum value for the check-flight data relative to the operational data are in agreement with past piston and turbine experience.

The cumulative frequency distributions for operational flights by flight condition shown in figure 5 indicate a much higher frequency during climb and descent than during the cruise condition. An asymmetry with a positive bias is also indicated for all three flight conditions.

The cumulative frequency distributions of combined positive and negative maneuver accelerations by flight condition are presented in figure 6. The frequency of occurrence of maneuver accelerations per mile of flight for climb was approximately the same as that for descent. The frequency of occurrence for each of the two flight conditions was about ten times that during cruise.

CONCLUDING REMARKS

The incremental maneuver normal accelerations collected during both passenger-carrying operational flights and check and training flights of a four-engine turbojet commercial transport airplane have been evaluated. The frequency

of occurrence of maneuver accelerations per mile of flight for climb was approximately the same as that for descent. The frequency of occurrence for each of these two flight conditions was about ten times that during cruise. This tendency is typical of transport operations, particularly for the turbojet transports.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., March 14, 1963.

REFERENCES

1. Staff of Langley Airworthiness Branch: Operational Experiences of Turbine-Powered Commercial Transport Airplanes. NASA TN D-1392, 1962.

2. Richardson, Norman R.: NACA VGH Recorder. NACA TN 2265, 1951.

3. Coleman, Thomas L., and Copp, Martin R.: Maneuver Accelerations Experienced by Five Types of Commercial Transport Airplanes During Routine Operations. NACA TN 3086, 1954.

4. Walker, Walter G., and Copp, Martin R.: Summary of VGH and V-G Data Obtained From Piston-Engine Transport Airplanes From 1947 to 1958. NASA TN D-29, 1959.